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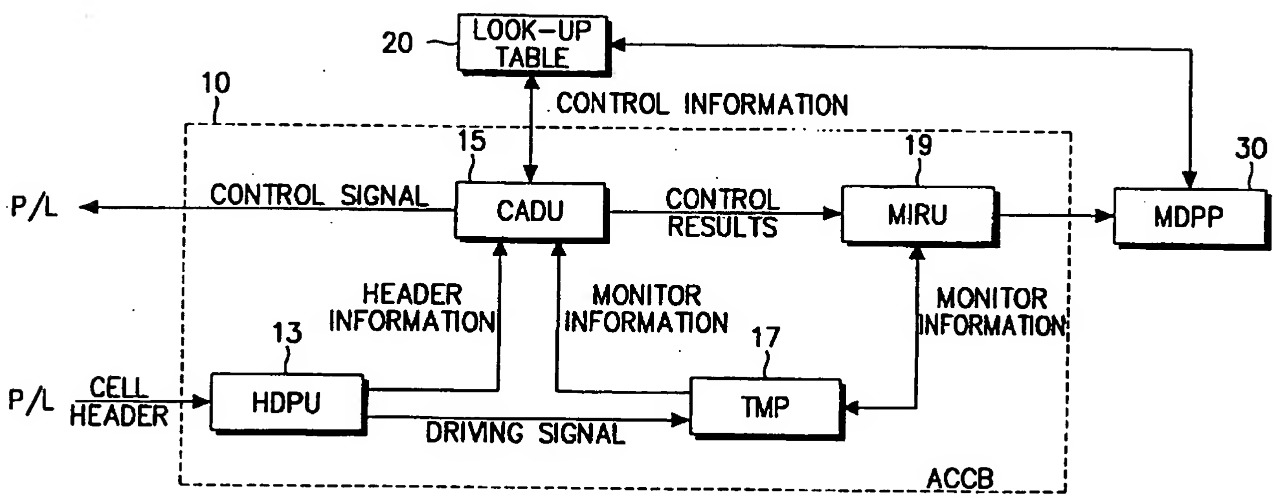
(54) **METHODE DE MONITORAGE ET DE GESTION DU TRAFIC EN TEMPS REEL DANS UN NOEUD DE COMMUTATION MTA**

(54) **METHOD FOR MONITORING AND CONTROLLING TRAFFIC IN REAL TIME IN AN ATM SWITCHING NODE**



(57) A method for monitoring and controlling traffic in real time at an asynchronous transfer mode (ATM) switching node, comprising the steps of retrieving the virtual path identifier (VPI)/virtual channel identifier (VCI) field and cell loss priority (CLP) field from the header of a received ATM cell to determine the validity of the cell by checking the effective value of the header for VPI/VCI field, comparing cell monitoring counter value (Cm) with cell control counter value (Cc) to detect violation of traffic parameter when the cell is determined to be valid, determining whether the present user's connection violates the negotiated parameter by means of traffic control data (Active_Idle) and CLP when the cell violates the traffic parameter, holding, tagging and discarding the cell according as the cell violates the negotiated parameter, transferring the result of controlling the valid cell to the physical layer to process the cell, and reporting the cell monitoring counter value to a control panel of upper hierarchy to reset the cell counter control value based on the cell monitoring counter value.

ABSTRACT OF THE DISCLOSURE

A method for monitoring and controlling traffic in real time at an asynchronous transfer mode (ATM) switching node, comprising the steps of retrieving the virtual path identifier (VPI)/virtual channel identifier (VCI) field and cell loss priority (CLP) field from the header of a received ATM cell to determine the validity of the cell by checking the effective value of the header for VPI/VCI field, comparing cell monitoring counter value (Cm) with cell control counter value (Cc) to detect violation of traffic parameter when the cell is determined to be valid, determining whether the present user's connection violates the negotiated parameter by means of traffic control data (Active_Idle) and CLP when the cell violates the traffic parameter, holding, tagging and discarding the cell according as the cell violates the negotiated parameter, transferring the result of controlling the valid cell to the physical layer to process the cell, and reporting the cell monitoring counter value to a control panel of upper hierarchy to reset the cell counter control value based on the cell monitoring counter value.

METHOD FOR MONITORING AND CONTROLLING TRAFFIC IN REAL TIME IN AN ATM SWITCHING NODE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of monitoring and controlling traffic in real time in an ATM switching node by controlling the cell transmission rate of various traffic sources having variable bit rates.

2. Description of the Related Art

The ATM (Asynchronous Transfer Mode) network generally requires means for controlling the traffic and bandwidth to effectively transmit information with QOS (Quality Of Service) demanded by the user. The traffic service classes usually provided by the ATM switching system are based on CBR (Constant Bit Rate), RT-VBR (Variable Bit Rate), NRT-VBR, ABR (Available Bit Rate), UBR (Unspecified Bit Rate), etc. Particularly among these, the VBR service has to be provided in real time as with video signals. Since it needs varieties of bandwidth and shows burst property, the switching node of an ATM network must be provided with means for monitoring and controlling the traffic in order to utilize the network resources over the negotiated traffic parameter. However, if the means for controlling the traffic does not properly work to meet variations of the traffic transmitted over the ATM network, it may cause traffic congestion in the network carrying the VBR traffic.

The GCRA (Generic Cell Rate Algorithm) recommended by the ATM

Forum to control the ATM traffic, which is also called 'virtual scheduling algorithm' or 'continuous-state leaky bucket algorithm', is to control the maximum cell transmission rate, cell delay variation, average cell transmission rate and burst allowance. This provides means to control the transmission rate of data cells inputted through the switch by means of limited values of the buffer and increments of the counter determined with traffics. Although GCRA is a simple algorithm with good performance to detect whether the negotiated cell parameter is met, it is not necessary to use this algorithm as UPC (Usage Parameter Control). Instead, any UPC algorithm may be installed provided that QOS may be guaranteed for a call to transmit cells according the negotiated parameter.

Originally, GCRA is proposed as an algorithm to control the cells by detecting violation of the negotiated cell parameter, and gives no rules for the other functions. However, the system designer tends to modify GCRA to monitor the traffic inputted to the switching node in order to measure the rates of using the band by the calls of all the users. In order to control the cell transmission rate, guarantee QOS, and improve the network performance, it is necessary to monitor the traffic transmitted over the network regardless of the ATM service classes. In addition, while it is possible to check the traffic loaded on the network by means of GCRA and the resource management (RM) cell for feedback control, these algorithms are not originally and mainly intended to monitor the traffic, so that the VBR traffic cannot be correctly monitored. Hence, such conventional technologies suffer the following drawbacks when employed to monitor and control the ATM traffic with various characteristics:

1. At least two counters, one for controlling the maximum cell transmission

rate and the other for the average cell transmission rate, are required to monitor and control a VBR and VC (Virtual Connection).

2. For allotting the network resources to VBR and ABR services are required the buffer size and leaky rate pairs according to the number of the connections. In addition, it is very difficult to uniformly control the network resources for the wideband services with various characteristics.

3. Since the control algorithm for transmitted data cells is executed only at the measurement time interval initially set, it is impossible to measure the real average cell transmission rate. Namely, the accuracy in the cell transmission rate control of GCRA depends on the size of the leaky bucket.

4. While the traffic flowing into the switching node may be controlled by setting the leaky rate, it is impossible to calculate in real time the rate used by all VC's of the resources. In addition, the leaky rate for a certain connection means continuous allotment of a fixed band to the connection, so that it is hardly expected to achieve the optimum efficiency of using the network resources.

5. The size of the buffer in the switch is increased with the burst characteristic of information, thus increasing hardware. In order to serve traffic with large burst characteristic, it is desirable to employ a system like the conventional FRP (Fast Reservation Protocol), which however does not provide the functions of monitoring and reporting the traffic. Besides, since the input data cell is first processed by the buffer, it is unavoidable to delay the process.

6. There is no suitable congestion control mechanism, because of the delay characteristic inherent in the high speed channel, which is necessary to control the congestion of the ATM network. Namely, the conventional congestion control mechanism checks the occupancy rate of the buffer provided in the switch, or measures RTT (Round Trip Time) by sending a special control cell to the network link in order to detect the congestion of the network. However, such detection is not performed in real time, so that it is difficult to cope with the overhead resulting from delay in processing or transmitting cell in each switch.

7. While GCRA may control the traffics flowing into the switching node in the conventional ATM network by setting the leaky rate and buffer size based on the parameter, it is impossible to actively readjust the traffic control data or allotted bandwidth when there flows into the switching node traffics having bit rates varying with time.

These drawbacks may be summarized as follows:

The conventional traffic control algorithm can hardly achieve the optimum effect of multiple statistics that is the best advantage of the ATM network. Moreover, even if there remains available parts in the network resources, QOS is frequently affected with the linked connection. Such problems are caused by the fact that most of the traffic control algorithms are not executed in real time, and the functions in the traffic control are performed independently with one another.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for monitoring and controlling traffic in real time in a switching node of an ATM network to guarantee QOS demanded by the user.

It is another object of the present invention to provide a method for controlling the cell transmission rate of VBR traffic flowing into an ATM switching node to optimize the efficiency of using the ATM network resources according to the input state of the traffic.

According to the present invention, a method for monitoring and controlling traffic in real time at an asynchronous transfer mode (ATM) switching node, comprising the steps of retrieving the virtual path identifier (VPI)/virtual channel identifier (VCI) field and cell loss priority (CLP) field from the header of a received ATM cell to determine the validity of the cell by checking the effective value of the header for VPI/VCI field, comparing cell monitoring counter value (Cm) with cell control counter value (Cc) to detect violation of traffic parameter when the cell is determined to be valid, determining whether the present user's connection violates the negotiated parameter by means of traffic control data (Active_Idle) and CLP when the cell violates the traffic parameter, holding, tagging and discarding the cell according as the cell violates the negotiated parameter, transferring the result of controlling the valid cell to the physical layer to process the cell, and reporting the cell monitoring counter value to a control panel of upper hierarchy to reset the cell counter control value based on the cell monitoring counter value.

The present invention will now be described more specifically with reference to the drawings attached only by of example.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram for illustrating the structure of an ATM cell control block for monitoring and controlling the traffic in real time according to the present invention;

Fig. 2 is a flow chart for illustrating the process of monitoring and controlling the ATM traffic according to the present invention;

Fig. 3 is a block diagram for illustrating the structure of a typical ATM cell header;

Fig. 4 is a cell diagram for illustrating determination of the capacity of a cell monitoring counter according to the present invention;

Fig. 5 is a view similar to Fig. 4 but illustrating the use of the cell monitoring counter value and cell control counter value according to the present invention;

Fig. 6 is a flow chart for illustrating the algorithm to monitor and control cells in real time according to the present invention;

Fig. 7 is a schematic diagram for showing CDV which is the range to allow cells without violating the traffic parameter;

Fig. 8 is a flow chart for illustrating the process to control the transmission rate of the input data cells and revise the allotment of the bandwidth in the

monitoring data processing part according to the present invention;

Fig. 9 is a schematic diagram for illustrating calculation of the monitoring counter value of the user's connection set in the transmission channel according to the present invention; and

Fig. 10 is a flow chart for illustrating the process to control the average cell transmission rate of data cells in real time by the monitoring data processing part (MDPP) according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Fig. 1, an ATM cell control block (ACCB) 10 comprises a header data processing unit (HDPU) 13, control action determination unit (CADU) 15, traffic monitor part (TMP) 17, and monitor information reporting unit (MIRU) 19, connected with a look-up table 20 and monitor data processing part (MDPP) 30.

ACCB 10 measures the time interval between two adjacent cells by a counter in an ATM layer, reporting it to MDPP 30. HDPU 13 receives a 5-byte cell header from a physical layer P/L to apply the header information to CADU 15 and a counter drive signal to TMP 17 according to a cell clock signal. The header information consists of VPI/VCI and CLP. CADU 15 transfers VPI/VCI to the look-up table 20, and compares the cell monitoring counter value Cm determined by TMP 17 with the cell control counter value Cc specified in the look-up table 20 applying the result to MIRU 19. Besides, CADU 15 transfers a control signal such as cell discard signal, tag signal, etc. resulting from the comparing to the data cell

buffer of the P/L to control the processing of the cell.

MIRU 19 is a logic unit reports the monitoring counter value Cm to a control panel by receiving the resultant value of CADU 15, so that MDPP 30 may revise the control counter value Cc when the monitoring counter value exceeds a specified control range. The look-up table 20 stores match flag value to determine validity of a cell according to VPI/VCI, control counter value Cc, A_I bit to determine violation of the negotiated parameter, and CNS value. MDPP 30 measures the cell transmission and average cell transmission rate of the presently input data based on the cell monitoring counter value Cm reported by MIRU 19, and calculates the information of the rate of using the network resources by all the users' connections to record the traffic control data suitable for the present situation of each user's connection into the look-up table 20 and revise the control counter value Cc.

Referring to Fig. 2, in step 101, ACCB 10 retrieves VPI/VCI and CLP fields from the 5-byte header of a 53-byte ATM cell received. The general structure of the 5-byte ATM cell header is shown in Fig. 3. In step 103, it is determined by means of the match flag value of the look-up table whether the received cell is validly generated by a rightly set connection. For example, if the match flag of VPI/VCI field equals '1', the cell is determined as valid. Or otherwise, if the match flag does not equal '1', the cell is determined as invalid, and discarded. If the cell is valid, the monitoring counter value Cm is compared with the control counter value Cc in step 105 to check violation of the traffic parameter. In this step is used the CDV predetermined during setting the connection to cope with cell concentration. Describing more specifically with reference to Fig. 7, if the monitoring counter value Cm comes within CDV specified around the control counter value Cc as

indicated by Cm2 or Cm3, the cell is allowed. If it is Cm1, the cell is determined as violating the traffic parameter. However, if it is Cm4, the cell is allowed with resetting the next control counter value Cc as Cm4.

In step 107, the traffic control data A_I (Active_Idle) bit is used to determine whether the present user's connection violates the negotiated parameter, and to control access to the unused bandwidth. For example, if A_I=1, the cell is determined as violating the negotiated traffic parameter, and if A_I=0, it is held. If the cell violates the negotiated parameter, it is discarded or tagged by the value of CLP field. The result of controlling the cell is transferred to P/L to process the cell while the cell control counter value Cm is reported to the control panel of upper hierarchy. The reporting of the monitoring counter value Cm is performed in several ways. Although it is most exact to report it every time that it does not agree with Cc, this causes the system to suffer a considerable load. Hence, it is preferable to report it only when the difference between Cm and Cc exceeds CDV. Otherwise, the report may be periodically made at a given time interval, whose optimum value may be determined based on the traffic characteristic and the capacity of calculating the traffic. Finally, the cell counter is reset to repeat the previous steps to process the next cell. The inventive method requires the following functions:

1. Receiving ATM Cell Header

Receiving the cell clock signal representing the system synchronizing signal as well as 5-byte cell header synchronized to the byte clock signal immediately after the cell clock signal. The cell clock signal is used to drive a binary counter to monitor cells. The cell header received is separated or recombined to be used for

monitoring and controlling cells.

2. Checking Validity of ATM Cell Header

The cell header is checked to determine whether the present cell is generated by a user's connection rightly set. This is achieved by sending VPI of 8 bits (12 bits for NNI (Network to Network Interface)) and VCI of 16 bits retrieved from the cell header to the look-up table and receiving the corresponding match flag from it.

3. Monitoring Input Cell

All the data cells generated by the VBR traffic source are monitored by a binary counter of specific bits. The capacity of the binary counter is variably adjusted according to the characteristics of the traffic served by the system. For example, the binary counter of 14 bits is to monitor data cells with a low speed up to 16kbps. Namely, in the case of 16kbps traffic, assuming that the link speed is 155.52Mbps, and the cell transmission rate of the traffic source is Rc, the time interval T_{icat} between two adjacent cells is obtained by the following Equation 1:

Equation 1

$$T_{icat} = \text{line speed} \div Rc$$

Calculating with 16kbps traffic by using Eq. 1, the time interval $T_{icat} = (155.52 \times 10^6) \div (16 \times 10^3) = 9720$(cell time). Hence, the binary counter must have a capacity of 14 bits to monitor the traffic because $2^{13} < 9720 < 2^{14}$. In this example, although the capacity is based on the minimum cell transmission rate, it may be

reduced more in the actual situation according to the kind of the traffic to monitor and the negotiated data transmission rate. For example, as shown in Fig. 4, the cell transmission rate of 6.48Mbps results in the time interval T_{icat} between the adjacent cells being 24, so that a counter of 5-bit capacity is sufficient to monitor the traffic. Likewise, the cell transmission rate of 12.96Mbps makes T_{icat} of 12 requiring a counter of 4 bits, and 51.84Mbps T_{icat} of 3 a counter of 2 bits. Namely, the capacity of the counter is decreased with increase of the traffic speed, so that the size of the hardware installed for policing in the ATM switch may be reduced in an environment such as wide band network or multimedia network.

In addition, the inventive cell monitoring mechanism is designed to monitor the transmission rate of data cells, and therefore, may be applied to control the rate-based ABR traffic. Further, the cell monitoring counter may be modified to count the number of the data cells flowing into the switch node in order to be applied to control the credit-based ABR traffic with good cell loss characteristic.

4. Receiving Cell Counter Control Value

When a user's data cell comes in, the look-up table 20 is read to retrieve the cell counter control value corresponding to VPI/VCI retrieved from the 5-byte cell header. The initial counter control value Cc immediately after setting the link connection is determined by the following Equation 2:

Equation 2

$$Cc = \text{cell size} \div (Rp \times \text{one\_cell\_time})$$

Wherein Rp represents the maximum cell transmission rate negotiated during

setting the link connection, and one_cell_time 2.726μsec from the ATM UNI (User-Network Interface) speed. The counter control value Cc may be applied to control the cell transmission rate of the rate-based ABR traffic without modification, and as control data to control the occupancy of the buffer according to the buffer control rule in the credit-based ABR traffic.

5. Controlling Cells

The precise controlling of cells is achieved by comparing the cell monitor counter control value Cm with the cell counter control value Cc. If Cm is greater than Cc, the cell does not violate the control parameter. Or otherwise, if Cm is smaller than Cc, the cell violates the control parameter. As shown in Fig. 5, if the control value of the present cell transmission rate is 10Mbps (identical to the counter control value of 16), Cm1 violates the traffic parameter, and Cm2 not. When finally determining violation of the parameter, the counter control value is used with CDV allowing cell delay from the traffic source to the monitoring part, which is to cope with the cell concentration due to statistical multiplicity. Meanwhile, the unique traffic control data A_I bit is used to determine whether the corresponding connection violates the negotiated parameter and to control access to the used bandwidth.

6. Reporting Cell Monitoring Counter Value

The information resulting from monitoring and controlling cells is reported to the control panel to obtain the statistical data for the data cell, and to modify the control information of the connection as desired. Since the monitoring counter value

Cm is greater than the control counter value Cc for most cases in VBR or burst traffic, the control counter value Cc is reset based on the monitoring counter value Cm. On the contrary, if Cm is smaller than Cc, the counter control value Cc is immediately changed by reporting the monitoring counter value, which is registered in the look-up table as the counter control value with setting of A_I bit.

Describing specifically the algorithm of Fig. 6 in connection with Figs. 1 to 5 and 7, HDPU 13 receives a cell of 53 bytes from P/L of an ATM network in step 201. Then, in step 203, it retrieves VPI/VCI and CLP fields from the header of the ATM cell of 5 bytes as shown in Fig. 3, transferring them to CADU 15, which in step 205 checks the validity of the cell based on the match flag of the corresponding VPI/VCI retrieved from the look-up table 20 as shown in Table 1.

Table 1. Example of Look-up Table

VPC/VCI 24 bits	Match Flag 1 bit	Cc 14 bits	CDV	A_I 1 bit	CNS 1 bit
# 10	0	---	xx	---	---
# 20	1	xx	xx	0	0 or 1
# 30	1	xx	xx	1	0 or 1
# 40	0 or 1	xx	xx	1(o)	0 or 1
.	.	.	.	.	.

Wherein xx: counter value; Match flag, A_I, CNS: Active High; (o): Option.

If the match flag of the corresponding VPI/VCI of the look-up table 20 is '1',

CADU 15 determines that the cell is valid generated from a rightly set connection, proceeding to step 209. On the contrary, if the match flag is not equal to '1', it determines the cell to be invalid, proceeding to step 207 to discard the cell and returning to step 201. In step 209, CADU 15 receives the monitor counter value Cm from TMP 17 while retrieving the control counter value Cc from the look-up table 20. In step 211, CADU 15 compares the monitor counter value Cm with the control counter value Cc to check violation of the traffic parameter. In this case is used CDV of the corresponding VPI/VCI, which is prescribed in the look-up table 20 upon setting the connection to cope with concentration of cells. If |Cc-Cm| is equal to or smaller than CDV, the cell is allowed as valid, terminating the monitoring and controlling of the cell, and proceeding to step 231 to stand by for the next cell. On the contrary, if |Cc-Cm| > CDV, it proceeds to step 212 to determine whether Cc > Cm. If Cm < Cc, it goes to step 213, or otherwise to step 227. In other words, if Cm is determined in step 211 to come within CDV, the cell is valid. On the contrary, if Cm does not come within CDV, the cell is determined in step 212 to be valid or invalid according as Cc < Cm. For example, as shown in Fig. 7, Cm2, Cm3 and Cm4 are valid, and Cm1 invalid.

In step 213, CADU 15 retrieves the traffic control data value A_I from the look-up table 20 to determine whether the present user's connection violates the negotiated parameter. If the value of the corresponding A_I bit is '1', it determines the cell to violate the parameter, proceeding to step 217. On the contrary, if the value of A_I bit is '0', it holds the cell in step 215, proceeding to step 227. In step 217, if the value of CLP retrieved from the cell header is '1', it proceeds to step 219 to send to P/L a discard signal to discard the cell. On the contrary, if the value of CLP is '0', CADU 15 sets the value of CLP bit to '1' in step 221, proceeding to step

223 to generate a control signal 'TAG' to P/L. Thereafter, it changes the value of PTI field to transmit ECN signal, displaying congestion of cells.

In step 227, CADU 15 reports the result of controlling to MIRU 19 to send the monitor counter value Cm to the control panel. Subsequently, in step 229, MDPP 30 revise the control counter value Cc in the look-up table 20 based on the monitor counter value Cm. This is to control the traffic of the next cell by considering the difference between the control counter value Cc and the monitor counter value Cm even if the presently received cell is valid. Thus, the traffic may be controlled in real time. Finally, in step 231, the timer (binary counter) is reset to return to step 201 to repeat the previous steps 201 to 231 to monitor and control the next cell in real time.

Referring to Fig. 8, MDPP controls the transmission rate of the data cell to newly allot the bandwidth according to the cell monitor counter value Cm transferred in real time from ACCB. When a data cell flows from the corresponding virtual channel VC#i set in an ATM network into the switching node, ACCB 10 obtains the monitor counter value Cm of the data cell transferred through MRIU 19 to MDPP 30. The monitor counter value Cm is obtained by counting the number of the cells of the reference virtual channel flowing through the transmission channel of 155.52Mbps at the time interval of 2.726μsec during the time interval between two adjacent data cells of the corresponding virtual channel VC#i which flow into the switching node. More specifically describing the calculation of the monitor counter value Cm with reference to Fig. 9, the reference virtual channel VC#1 transmits a cell at a transmission rate of 155.2Mbps at every 2.726μsec while the virtual channel VC#i transmits a cell at every 5 cells of the reference virtual channel

VC#1. Thus, the monitor counter value Cm of the virtual channel VC#i becomes '5' based on 2.726μsec. This value Cm is used to calculate the cell transmission rate Rc(t) of the virtual channel VC#i transferring cells to the switching node at time 't'.

Referring again to Fig. 8, in step 300, MDPP 30 receives the monitor counter value Cm(t) of the data cell through the virtual channel VC#i at time 't', proceeding to step 302 to calculate the present cell transmission rate Rc(t) of the data cell arriving at time 't' by means of the following Equation 3:

Equation 3

Rc(t) = transmission channel link speed / Cm(t)

In step 304, MDPP 30 determines whether the value obtained by subtracting the bandwidth Y(t) having been allotted to the virtual channel VC#i before time 't' from the total bandwidth X(t) presently allotted to the transmission channel and adding thereto the bandwidth corresponding to the present cell transmission rate Rc(t) of the virtual channel VC#i at time 't', exceeds the whole bandwidth Bx of the transmission channel. If it does not exceed the whole bandwidth Bx, MDPP 30 goes to step 306 to determine whether the monitor counter value Cm of the present virtual channel VC#i is greater than the counted value Cp(i) of the maximum cell transmission rate negotiated in advance upon setting the connection. If Cm(t) is greater than Cp(i), MDPP 30 goes to step 308 to revise the cell control counter value Cc(t+1) of the look-up table 20 with the present monitor counter value Cm(t). Subsequently, MDPP 30 goes to step 310 to revise, as in the following Equation 4, the total bandwidth X(t+1) to be newly allotted to the transmission channel with the value obtained by subtracting the bandwidth Y(t) allotted to the virtual channel

VC#i from the total bandwidth X(t) allotted to the transmission channel at time 't' and adding thereto the bandwidth corresponding to the present cell transmission rate Rc(t) of the virtual channel VC#i calculated at time 't' in step 302, and also to revise the bandwidth Y(t+1) to be allotted to the virtual channel VC#i with the bandwidth corresponding to the present cell transmission rate Rc(t):

Equation 4

$$X(t+1) = X(t) - Y(t) + Rc(t)$$

On the contrary, if Cm(t) is smaller than Cp(i) in step 306, MDPP 30 goes to step 312 to revise the cell control counter value Cc(t+1) of the look-up table 20 with the counted value Cp(i) of the maximum cell transmission rate negotiated in advance, and sets A_I bit as '1'. Subsequently MDPP 30 goes to step 314 to obtain the present cell transmission rate Rc(t) by dividing the transmission channel link speed by the counted value Cp(i) of the maximum cell transmission rate as in the following Equation 5:

Equation 5

$$Rc(t) = \text{transmission channel link speed} / Cp(i)$$

Then, MDPP 30 goes to step 310 to revise the total bandwidth X(t+1) allotted to the transmission channel and the bandwidth Y(t+1) allotted to the virtual channel VC#i based on the present cell transmission rate Rc(t) obtained in step 314.

On the contrary, in step 304, if the value obtained by subtracting the bandwidth Y(t) having been allotted to the virtual channel VC#i before time 't' from

the total bandwidth X(t) presently allotted to the transmission channel and adding therto the bandwidth corresponding to the present cell transmission rate Rc(t) of the virtual channel VC#i at time 't', exceeds the whole bandwidth Bx of the transmission channel, MDPP 30 goes to step 316 to set the present cell transmission rate Rc(t) of the virtual channel VC#i to the value obtained by subtracting the total bandwidth X(t) allotted to the transmission channel from the whole bandwidth Bx and adding thereto the bandwidth Y(t) allotted to the virtual channel VC#i, as in the following Equation 6:

Equation 6

$$Rc(t) = Bx-(X(t) - Y(t))$$

In step 318, MDPP 30 determines whether the cell monitor Cm(t) corresponding to the present virtual channel VC#i is greater than the counted value Cp(i) of the maximum cell transmission rate negotiated in advance. If so, MDPP 30 goes to step 320 to revise the cell control counter value Cc(t+1) of the look-up table 20 with the value obtained by dividing the transmission channel link speed by the present cell transmission rate Rc(t), as in the following Equation 7, and sets the bit of the congestion control signal to notify congestion of the present network:

Equation 7

$$Cc(t+1) = \text{transmission channel link speed} / Rc(t)$$

In step 310, MDPP 30 revises the total bandwidth X(t+1) allotted to the transmission channel and the bandwidth Y(t+1) allotted to the virtual channel VC#i based on the present cell transmission rate Rc(t) calculated in step 316.

On the contrary, in step 318, if Cm(t) is smaller than Cp(i), MDPP 30 goes to step 322 to revise the cell control counter value Cc(t+1) of the look-up table with the counted value Cp(i) of the maximum cell transmission rate negotiated in advance, and sets A_I bit as '1'. Then, in step 310, MDPP 30 revises the total bandwidth X(t+1) allotted to the transmission channel and the bandwidth Y(t+1) allotted to the virtual channel VC#i based on the present cell transmission rate Rc(t) calculated in step 316. Thus, even if the data cells of an arbitrary virtual channel flow into the switching node of the ATM network at VBR with time, MDPP 30 monitors them in real time so as to variably allot the allowable bandwidth according to the presently monitored cell transmission rate, thereby making efficient use of the bandwidth.

Hereinafter will be specifically described the process of controlling the average transmission rate of data cell in real time by MDPP 30 with reference to Figs. 1, 8, 9 and 10. When the k'th data cell of the virtual channel VC#i set in the ATM network flows into the ATM switching node, ACCB 10 obtains the present monitor counter value Cm(k) of the data cell transferred through MIRU 19 to MDPP 30, which in step 500 receives the monitor counter value Cm(k) of the k'th data cell of the virtual channel VC#i, proceeding to step 502 to calculate the time t(k) when the cell has arrived. Then, in step 504, MDPP 30 calculates the present cell transmission rate Rc(k) of the k'th data cell, as shown in Fig. 8. In step 506, it determines whether the cell arrival time t(k) exceeds the measurement time (MT) of the average cell transmission rate prescribed during setting the connection. Although the average cell transmission rate may actually be obtained by dividing the accumulation of all the cell transmission rates of the cells flowing through the virtual channel VC#i from beginning to end by the time of ending the transmission,

it is of no use for process the traffic in real time. Hence, in order to control the traffic in real time, it is necessary to periodically calculate the average cell transmission rate of the virtual channel VC#i. The MT of the average cell transmission rate means the time intervals properly set by the user according to the characteristics of the traffics, at which time intervals are measured the average cell transmission rates of the virtual channels set. If t(k) is smaller than MT, MDPP 30 goes to step 508 to add the transmission rate Rc(k) of the presently arriving cell to the value X of the dummy variable accumulating the transmission rates of the cells corresponding to the virtual channel VC#i, as in the following Equation 8:

Equation 8

$$X = X + [Rc(k) \times \{t(k) - t(k-1)\}]$$

Then, returning to step 500, MDPP 30 stands by to receive the monitor counter value Cm of the k+1'st data cell of the virtual channel VC#i to arrive at time t(k+1).

On the contrary, if t(k) is greater than MT, MDPP 30 proceeds to the step 510 to calculate the average cell transmission rate Rs up to the cell arrival time t(k), as in the following Equation 9:

Equation 9

$$Rs = [X+Rc(k) \times \{t(k)-t(k-1)\}] / t(k)$$

Thus, the average cell transmission rate Rs up to the cell arrival time t(k) is obtained by dividing the accumulation of the transmission rates of the cells

corresponding to the virtual channel VC#i by the cell arrival time t(k). In step 512, MDPP 30 determines whether the average cell transmission rate Rs at the time t(k) is greater than the average cell transmission rate Ra_negotiated negotiated during setting the connection of the virtual channel VC#1. If Rs is smaller than Ra_negotiated, MDPP 30 determines that the data cells of the virtual channel VC#i do not violate the average cell transmission rate, then proceeding to step 514 to revise the cell control counter value Cc of the look-up table 20 with the monitor counter value Cm(k), and reset A_I bit to '0'.

On the contrary, in step 512, if Rs is greater than Ra_negotiated, the cells of the virtual channel VC#I flowing into the switching node violate the average cell transmission rate, so that MDPP 30 goes to step 516 to revise the cell control counter value Cc of the look-up table with the value obtained by dividing the transmission channel link speed by the negotiated average cell transmission rate Ra_negotiated, as in the following Equation 10, and sets A_I bit as '1'.

Equation 10

Cc = transmission channel link speed / Ra_negotiated

Then, MDPP 30 goes to step 518 to add the transmission rate Rc(k) of the cell arriving at the time t(k) to the value X of the dummy variable accumulating the transmission rates of the cells corresponding to the virtual channel VC#I, and also accumulating the given time interval between the measurement times TM's to MT at every routine, as in the following Equation 11:

Equation 11

$$X = X + [Rc(k) \times \{t(k) - t(k-1)\}]$$
$$MT = MT + ACRMT$$

Thus, it is possible to control the average cell transmission rate of the virtual channel in real time by calculating the average cell transmission rate at a given time interval.

As described above, the invention provides an algorithm to monitor and control the ATM traffic in real time, which may be applied to various ATM services such as VBR, ABR and UBR. This optimizes the utilization of the network resources by allotting the unused bandwidth to the virtual channels requiring more capacity without degrading QOS. While the present invention has been described with specific embodiments accompanied by the attached drawings, it will be appreciated by those skilled in the art that various changes and modifications may be made thereto without departing the gist of the present invention.

WHAT IS CLAIMED IS:

1. A method for monitoring and controlling traffic in real time at an asynchronous transfer mode (ATM) switching node, comprising the steps of:

retrieving the virtual path identifier (VPI)/virtual channel identifier (VCI) field and cell loss priority (CLP) field from the header of a received ATM cell to determine the validity of said cell by checking the effective value of said header for VPI/VCI field;

comparing cell monitoring counter value (Cm) with cell control counter value (Cc) to detect violation of traffic parameter when said cell is determined to be valid;

determining whether the present user's connection violates the negotiated parameter by means of traffic control data (Active_Idle) and CLP when said cell violates said traffic parameter;

holding, tagging and discarding said cell according as said cell violates said negotiated parameter;

transferring the result of controlling the valid cell to the physical layer to process said cell; and

reporting said cell monitoring counter value to a control panel of upper hierarchy to reset said cell counter control value based on said cell monitoring

counter value.

2. A method as defined in Claim 1, wherein said cell monitoring counter value is the time interval between two adjacent cells measured by a binary counter in the ATM layer.

3. A method as defined in Claim 1, wherein said cell control counter value is determined by the following Equation 12 immediately after setting connection, specified in a look-up table, and then revised according to said cell monitoring counter value during cell processing:

Equation 12

$$Cc = \text{cell size} \div (Rp \times \text{one\_cell\_time})$$

Wherein Cc represents the cell control counter value immediately after setting the connection, Rp the maximum cell transmission rate negotiated during setting the connection, and one_cell_time 2.726μsec obtained from the interface speed between the user's ATM networks.

4. A method as defined in Claim 1, wherein the step of comparing cell monitoring counter value with cell control counter value to detect violation of traffic parameter is to allow said cell if said cell monitoring counter value comes within an arbitrary cell delay variation (CDV) specified around said cell control counter value, or otherwise to determine said cell as violating said traffic parameter.

5. A method as defined in Claim 4, wherein said CDV is predetermined during setting the connection, and specified in said look-up table.

6. A method as defined in Claim 1, including the further step of standing by to process the next cell after discarding said cell determined as invalid.

7. A method as defined in Claim 1, including the further step of standing by to process the next cell after allowing said cell determined as valid with terminating the monitoring and controlling of said cell.

8. A method as defined in Claim 2, wherein said binary counter has the minimum bit capacity including the arriving interval between the adjacent cells determined by the following Equation 13:

Equation 13

T_{icat} = line speed $\div$ Rc

Wherein line speed represents the link speed of the traffic, Rc the cell transmission rate of a traffic source, and T_{icat} the arriving interval between the adjacent cells.

9. A method as defined in Claim 1, wherein said control panel controls the transmission rate of a virtual channel transmitting said cell at VBR according to said cell monitoring counter value.

10. A method as defined in Claim 9, wherein the step of controlling said cell transmission rate comprises the steps of:

measuring the present transmission rate of said cell according to said cell monitoring counter value;

resetting A_I bit after revising said cell control counter value specified in said look-up table with said cell monitoring counter value when the transmission channel has a remaining bandwidth enough to allot the bandwidth according to the present cell transmission rate to said virtual channel and said present cell transmission rate is lower than the maximum cell transmission rate previously negotiated;

revising the total bandwidth allotted on said transmission channel before arrival of the cell belonging to said virtual channel so as to include said present cell transmission rate; and

allotting the bandwidth according to said present cell transmission rate.

11. A method as defined in Claim 10, wherein the step of controlling said cell transmission rate comprises the steps of:

allotting to said virtual channel the bandwidth remaining after subtracting the total bandwidth allotted on said transmission channel before the arrival of said cell from the total bandwidth of said transmission channel when the transmission channel does not have a remaining bandwidth enough to allot the bandwidth according to said present cell transmission rate to said virtual channel;

setting a congestion control signal bit after revising said cell control counter value with the value obtained by dividing the link speed of said transmission channel by the present cell transmission rate of the revised virtual channel when said present cell transmission rate is lower than said maximum cell transmission

rate;

setting said A_I bit after revising said cell control counter value with the value according to said maximum cell transmission rate when said present cell transmission rate is higher than said maximum cell transmission rate; and

revising the total bandwidth allotted on said transmission channel before the arrival of the cell belonging to said virtual channel to include the bandwidth additionally allotted said virtual channel.

12. A method as defined in Claim 10, further including the steps of:

setting A_I bit after revising said cell control counter value specified in said look-up table with the maximum counted value according to said maximum cell transmission rate when the transmission channel has a remaining bandwidth enough to allot the bandwidth according to said present cell transmission rate to said virtual channel and said present cell transmission rate is higher than the maximum cell transmission rate previously negotiated;

resetting said present cell transmission rate with the value obtained by dividing the link speed of said transmission path by said maximum counted value; and

revising the total bandwidth allotted on said transmission channel before the arrival of the cell belonging to said virtual channel so as to allot the bandwidth according to the reset cell transmission rate to said virtual channel.

13. A method for monitoring and controlling traffic in real time at an asynchronous transfer mode (ATM) switching node, which comprises an ATM cell control block for measuring the time interval between two adjacent cells by a counter in an ATM layer to report it to a monitoring data processing part, and a look-up table for specifying the control data and the effective value of the header of a received ATM cell according to VPI/VCI and violation determination value, comprising the steps of:

retrieving VPI/VCI field and CLP field from said header;

determine the validity of said cell by checking the effective value of said header for VPI/VCI field;

comparing cell monitoring counter value with cell control counter value to detect violation of traffic parameter when said cell is determined to be valid;

determining whether the present user's connection violates the negotiated parameter by means of traffic control data and CLP when said cell violates said traffic parameter;

holding, tagging and discarding said cell according as said cell violates said negotiated parameter;

transferring the result of controlling the valid cell to the physical layer to process said cell; and

reporting said cell monitoring counter value to a control panel of upper hierarchy to reset said cell counter control value based on said cell monitoring counter value.

14. A method as defined in Claim 13, wherein said cell monitoring counter value is the time interval between two adjacent cells measured by a binary counter in the ATM layer.

15. A method as defined in Claim 13, wherein said cell control counter value is determined by the following Equation 14 immediately after setting connection, specified in a look-up table, and then revised according to said cell monitoring counter value during cell processing:

Equation 14

$$Cc = \text{cell size} \div (Rp \times \text{one\_cell\_time})$$

Wherein Cc represents the cell control counter value immediately after setting the connection, Rp the maximum cell transmission rate negotiated during setting the connection, and one_cell_time 2.726μsec obtained from the interface speed between the user's ATM networks.

16. A method as defined in Claim 13, wherein the step of comparing cell monitoring counter value with cell control counter value to detect violation of traffic parameter is to allow said cell if said cell monitoring counter value comes within an arbitrary CDV specified around said cell control counter value, or otherwise to determine said cell as violating said traffic parameter.

17. A method as defined in Claim 16, wherein said CDV is predetermined during setting the connection, and specified in said look-up table.

18. A method as defined in Claim 13, including the further step of standing by to process the next cell after discarding said cell determined as invalid.

19. A method as defined in Claim 13, including the further step of standing by to process the next cell after allowing said cell determined as valid with terminating the monitoring and controlling of said cell.

20. A method as defined in Claim 14, wherein said binary counter has the minimum bit capacity including the arriving interval between the adjacent cells determined by the following Equation 15:

Equation 15

T_{icat} = line speed $\div$ Rc

Wherein line speed represents the link speed of the traffic, Rc the cell transmission rate of a traffic source, and T_{icat} the arriving interval between the adjacent cells.

21. A method as defined in Claim 13, wherein the step of controlling said cell transmission rate by said monitoring data processing part comprises the steps of:

measuring the present transmission rate of said cell according to said cell

monitoring counter value;

resetting A_I bit after revising said cell control counter value specified in said look-up table with said cell monitoring counter value when the transmission channel has a remaining bandwidth enough to allot the bandwidth according to the present cell transmission rate to said virtual channel and said present cell transmission rate is lower than the maximum cell transmission rate previously negotiated;

revising the total bandwidth allotted on said transmission channel before arrival of the cell belonging to said virtual channel so as to include said present cell transmission rate; and

allotting the bandwidth according to said present cell transmission rate.

22. A method as defined in Claim 21, wherein the step of controlling said cell transmission rate by said monitoring data processing part comprises the steps of:

allotting to said virtual channel the bandwidth remaining after subtracting the total bandwidth allotted on said transmission channel before the arrival of said cell from the total bandwidth of said transmission channel when the transmission channel does not have a remaining bandwidth enough to allot the bandwidth according to said present cell transmission rate to said virtual channel;

setting a congestion control signal bit after revising said cell control counter

value with the value obtained by dividing the link speed of said transmission channel by the present cell transmission rate of the revised virtual channel when said present cell transmission rate is lower than said maximum cell transmission rate;

setting said A_I bit after revising said cell control counter value with the value according to said maximum cell transmission rate when said present cell transmission rate is higher than said maximum cell transmission rate; and

revising the total bandwidth allotted on said transmission channel before the arrival of the cell belonging to said virtual channel to include the bandwidth additionally allotted said virtual channel.

23. A method as defined in Claim 21, further including the steps of:

setting A_I bit after revising said cell control counter value specified in said look-up table with the maximum counted value according to said maximum cell transmission rate when the transmission channel has a remaining bandwidth enough to allot the bandwidth according to said present cell transmission rate to said virtual channel and said present cell transmission rate is higher than the maximum cell transmission rate previously negotiated;

resetting said present cell transmission rate with the value obtained by dividing the link speed of said transmission path by said maximum counted value; and

revising the total bandwidth allotted on said transmission channel before the arrival of the cell belonging to said virtual channel so as to allot the bandwidth according to the reset cell transmission rate to said virtual channel.

24. A method for monitoring and controlling traffic in real time at an ATM switching node, which comprises an ATM cell control block for measuring the time interval between two adjacent cells by a counter in an ATM layer to report it to a monitoring data processing part, and a look-up table for specifying the cell control counter value and the effective value of the header of a received ATM cell according to VPI/VCI, traffic control data value for serving as a reference to determine violation of the negotiated traffic parameter, and CDV, comprising the steps of:

retrieving VPI/VCI field and CLP field from the 5-byte header of the ATM cell of 53 bytes received from a physical layer;

determining the validity of said cell by checking the effective value of said header for VPI/VCI field transferred to said look-up table;

retrieving said cell control counter value from said look-up data and the cell monitoring counter value obtained by measuring the time interval between two adjacent cells from a traffic monitor part when said cell is determined as valid;

determining said cell as not violating said traffic parameter when said cell monitoring counter value comes within said CDV specified around said cell control counter value or is greater than said cell control counter value, or as violating it

when said cell monitoring counter value does not come within said CDV and is smaller than said control counter value;

determining whether the present user's connection violates the negotiated parameter by means of said traffic control data value when said cell violates said traffic parameter;

tagging or discarding said cell according to CLP field value when said cell is determined as violating said negotiated parameter;

transferring the result of controlling the valid cell to the physical layer to process said cell;

reporting said cell monitoring counter value to a control panel of upper hierarchy to reset said cell counter control value based on said cell monitoring counter value; and

resetting the counter upon completion of monitoring and controlling said received cell to repeat the previous steps for processing the next cell.

25. A method as defined in Claim 24, wherein the time interval between two adjacent cells is measured by a binary counter in the ATM layer.

26. A method as defined in Claim 25, wherein said binary counter has the minimum bit capacity including the arriving interval between the adjacent cells determined by the following Equation 16:

Equation 16

T_{icat} = line speed ÷ Rc

Wherein line speed represents the link speed of the traffic, Rc the cell transmission rate of a traffic source, and T_{icat} the arriving interval between the adjacent cells.

27. A method as defined in Claim 24, wherein said cell control counter value is determined by the following Equation 17 immediately after setting connection, specified in a look-up table, and then revised according to said cell monitoring counter value during cell processing:

Equation 17

Cc = cell size ÷ (Rp x one_cell_time)

Wherein Cc represents the cell control counter value immediately after setting the connection, Rp the maximum cell transmission rate negotiated during setting the connection, and one_cell_time 2.726μsec obtained from the interface speed between the user's ATM networks.

28. A method as defined in Claim 24, including the further step of standing by to process the next cell after discarding said cell determined as invalid.

29. A method as defined in Claim 24, including the further step of standing by to process the next cell after allowing said cell determined as valid with terminating the monitoring and controlling of said cell.

30. A method as defined in Claim 24, wherein said traffic control data

value serves as a reference to determine whether the corresponding connection violates the negotiated traffic parameter and to control access to the unused bandwidth.

31. A method as defined in Claim 24, further including the step of displaying the congestion of cells by changing PTI field of said cell header to transmit ECN signal upon said tagging.

32. A method as defined in Claim 24, further including the step of holding said cell when said cell is determined as valid according as said cell violates said negotiated parameter.

33. A method as defined in Claim 24, wherein the step of controlling said cell transmission rate by said monitoring data processing part comprises the steps of:

measuring the present transmission rate of said cell according to said cell monitoring counter value;

resetting A_I bit after revising said cell control counter value specified in said look-up table with said cell monitoring counter value when the transmission channel has a remaining bandwidth enough to allot the bandwidth according to the present cell transmission rate to said virtual channel and said present cell transmission rate is lower than the maximum cell transmission rate previously negotiated;

revising the total bandwidth allotted on said transmission channel before arrival of the cell belonging to said virtual channel so as to include said present cell transmission rate; and

allotting the bandwidth according to said present cell transmission rate.

34. A method as defined in Claim 33, wherein the step of controlling said cell transmission rate by said monitoring data processing part comprises the steps of:

allotting to said virtual channel the bandwidth remaining after subtracting the total bandwidth allotted on said transmission channel before the arrival of said cell from the total bandwidth of said transmission channel when the transmission channel does not have a remaining bandwidth enough to allot the bandwidth according to said present cell transmission rate to said virtual channel;

setting a congestion control signal bit after revising said cell control counter value with the value obtained by dividing the link speed of said transmission channel by the present cell transmission rate of the revised virtual channel when said present cell transmission rate is lower than said maximum cell transmission rate;

setting said A_I bit after revising said cell control counter value with the value according to said maximum cell transmission rate when said present cell transmission rate is higher than said maximum cell transmission rate; and

revising the total bandwidth allotted on said transmission channel before the arrival of the cell belonging to said virtual channel to include the bandwidth additionally allotted said virtual channel.

35. A method as defined in Claim 33, further including the steps of:

setting A_I bit after revising said cell control counter value specified in said look-up table with the maximum counted value according to said maximum cell transmission rate when the transmission channel has a remaining bandwidth enough to allot the bandwidth according to said present cell transmission rate to said virtual channel and said present cell transmission rate is higher than the maximum cell transmission rate previously negotiated;

resetting said present cell transmission rate with the value obtained by dividing the link speed of said transmission path by said maximum counted value; and

revising the total bandwidth allotted on said transmission channel before the arrival of the cell belonging to said virtual channel so as to allot the bandwidth according to the reset cell transmission rate to said virtual channel.

for serving as a reference to determine violation of the negotiated traffic parameter

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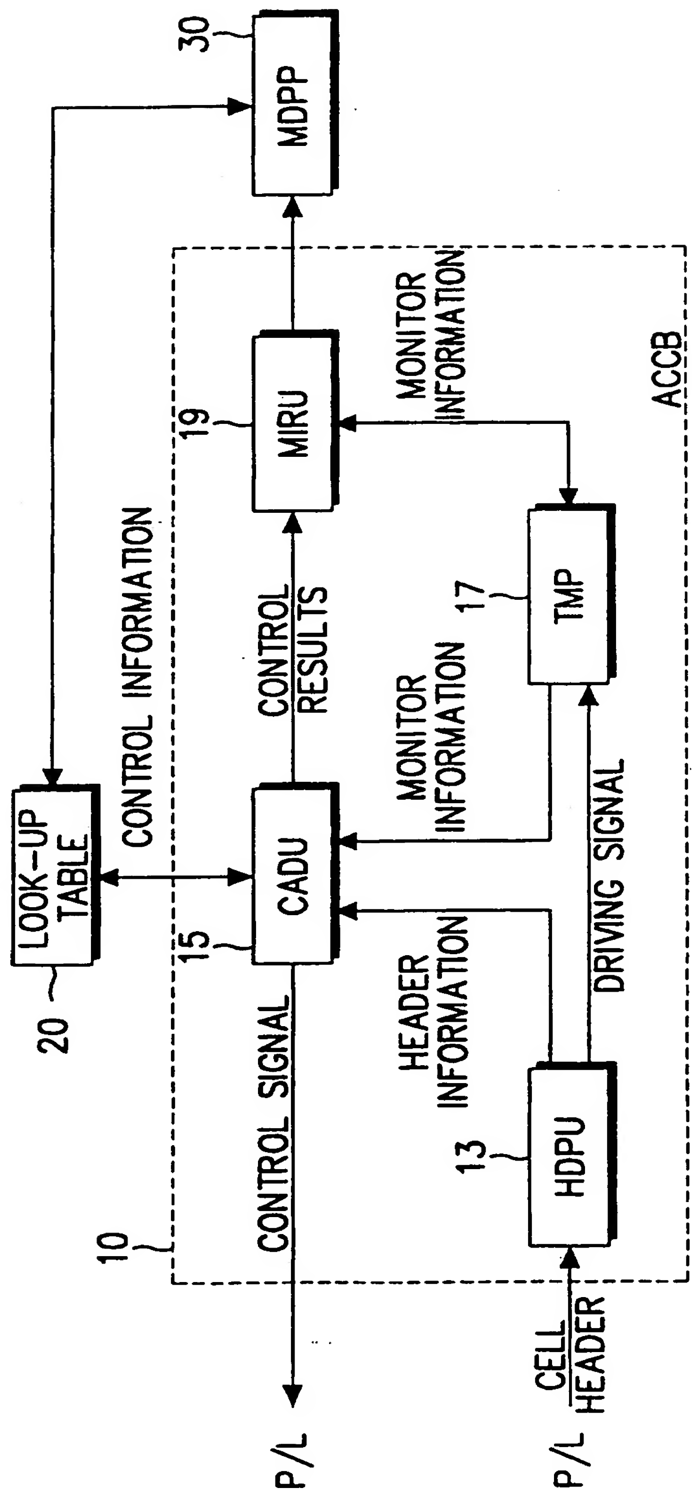
Patent Agents



30
MDPP
LOOK-UP TABLE
20
CONTROL INFORMATION
CADU
15
MIRU
19
CONTROL RESULTS
MONITOR INFORMATION
MONITOR INFORMATION
TMP
17
HEADER INFORMATION
DRIVING SIGNAL
HDPU
13
CONTROL SIGNAL
10
ACCB
P/L
P/L
CELL HEADER

FIG. 1

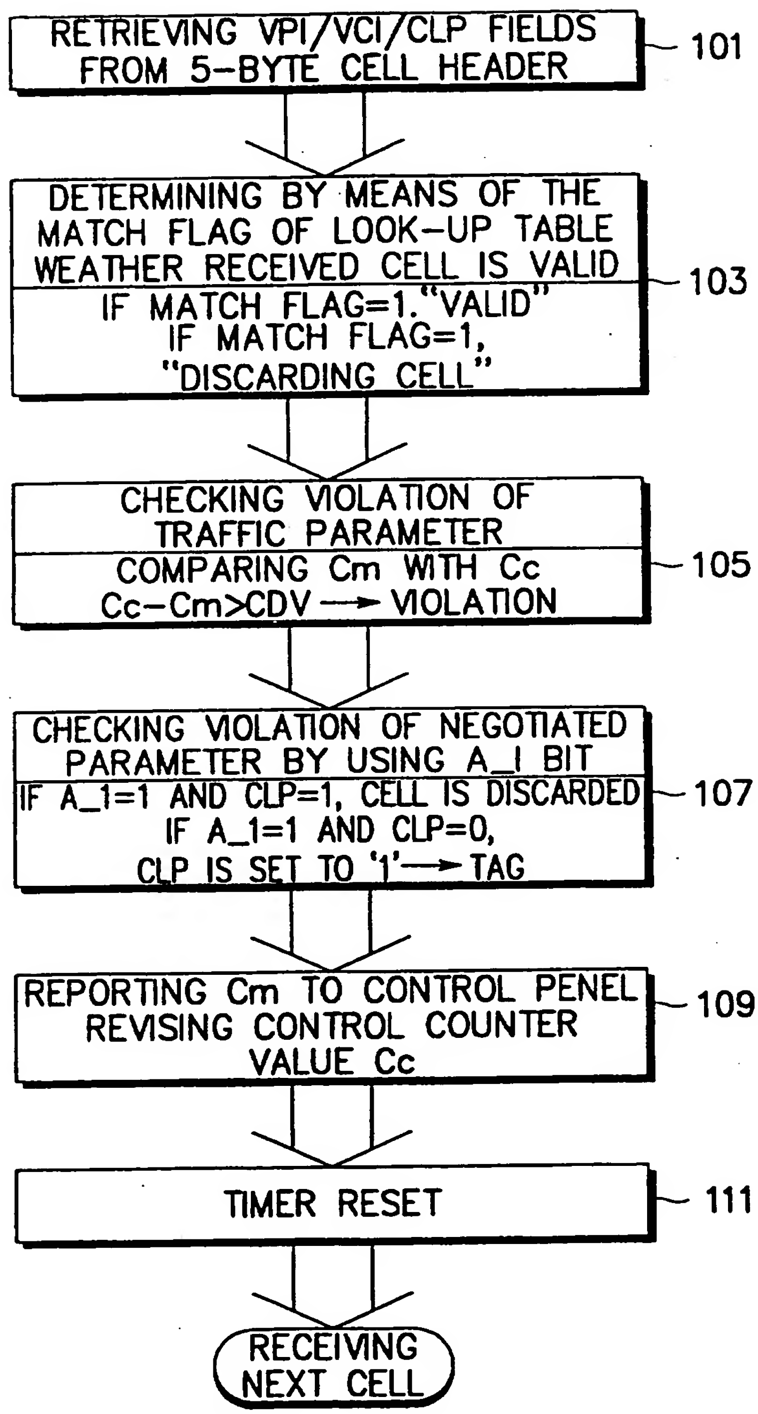
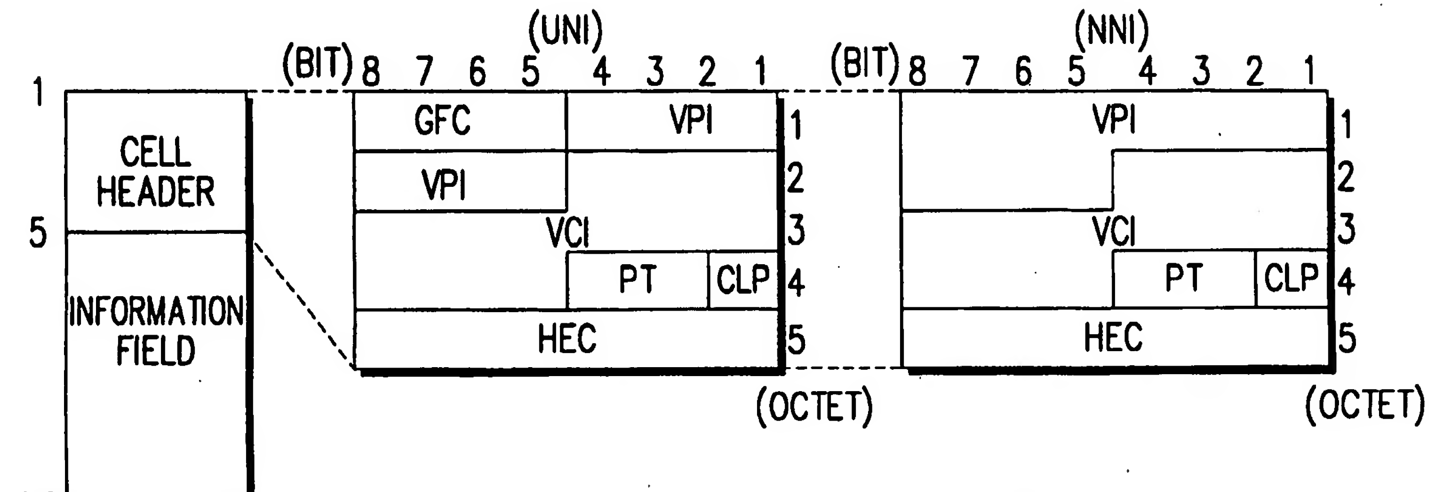

RETRIEVING VPI/VCI/CLP FIELDS FROM 5-BYTE CELL HEADER
101
DETERMINING BY MEANS OF THE MATCH FLAG OF LOOK-UP TABLE WEATHER RECEIVED CELL IS VALID
IF MATCH FLAG=1."VALID"
IF MATCH FLAG=1,
"DISCARDING CELL"
103
CHECKING VIOLATION OF TRAFFIC PARAMETER
COMPARING Cm WITH Cc
Cc-Cm>CDV → VIOLATION
105
CHECKING VIOLATION OF NEGOTIATED PARAMETER BY USING A_I BIT
IF A_1=1 AND CLP=1, CELL IS DISCARDED
IF A_1=1 AND CLP=0,
CLP IS SET TO '1' → TAG
107
REPORTING Cm TO CONTROL PENEL
REVISING CONTROL COUNTER VALUE Cc
109
TIMER RESET
111
RECEIVING NEXT CELL

FIG. 2



GFC: GENERIC FLOE CONTROL
VCI: VIRTUAL CHANNEL IDENTIFIER
HEC: HEADER ERROR CONTROL

VPI: VIRTUAL PATH IDENTIFIER
PTI: PAYLOAD TYPE INDICATOR
CLP: CELL LOSS PRIORITY

FIG. 3

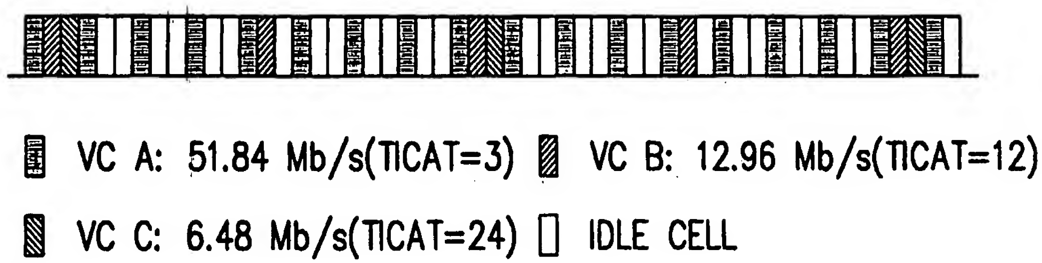
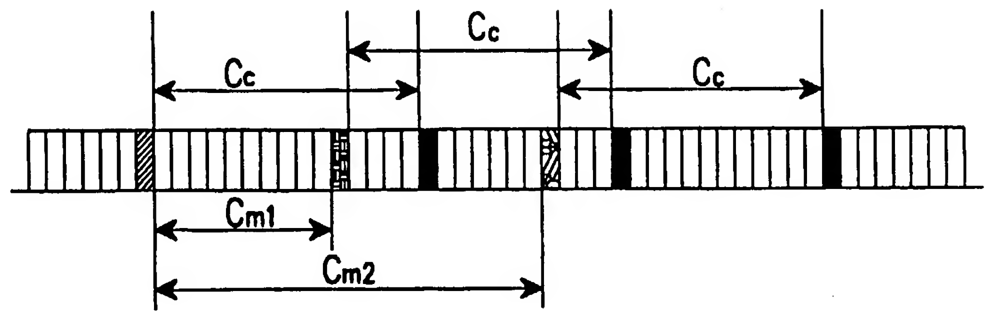

VC A: 51.84 Mb/s(TICAT=3)
VC B: 12.96 Mb/s(TICAT=12)
VC C: 6.48 Mb/s(TICAT=24)
IDLE CELL

FIG. 4



C_{m1} IS 11 (EQUIVALENT TO 14.138 Mb/s)

C_{m2} IS 23 (EQUIVALENTTO TO 6.762 Mb/s)

THE PREVIOUS CELL

POINT WHERE THE NEXT COMPLIANT CELL SHOULD EXCEED

FIG. 5

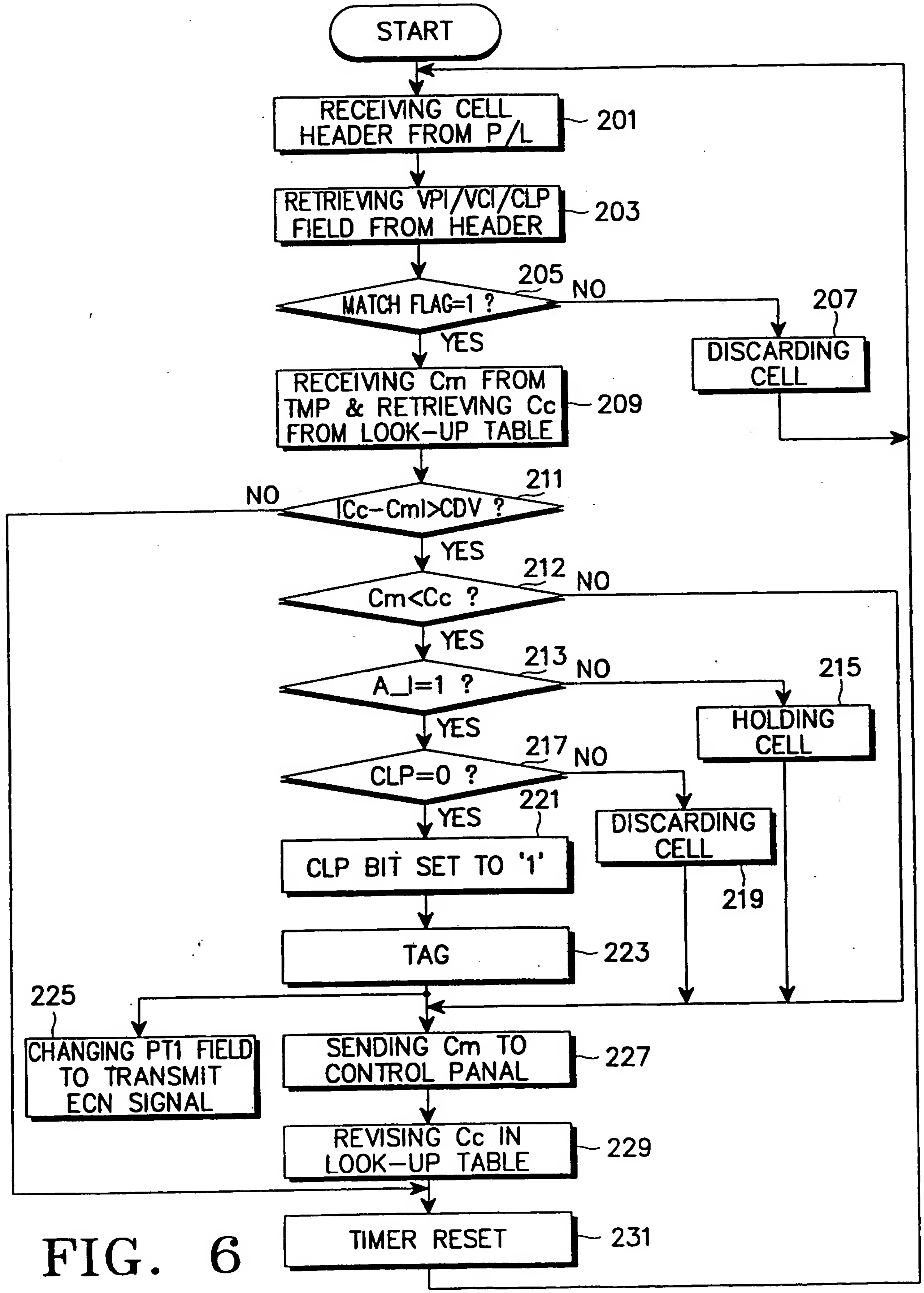

START
RECEIVING CELL HEADER FROM P/L
201
RETRIEVING VPI/VCI/CLP FIELD FROM HEADER
203
205
MATCH FLAG=1 ?
NO
YES
207
DISCARDING CELL
RECEIVING Cm FROM TMP & RETRIEVING Cc FROM LOOK-UP TABLE
209
211
|Cc-Cm|>CDV ?
NO
YES
212
Cm<Cc ?
NO
YES
213
A_I=1 ?
NO
YES
215
HOLDING CELL
217
CLP=0 ?
NO
YES
221
DISCARDING CELL
219
CLP BIT SET TO '1'
TAG
223
225
CHANGING PT1 FIELD TO TRANSMIT ECN SIGNAL
SENDING Cm TO CONTROL PANAL
227
REVISING Cc IN LOOK-UP TABLE
229
TIMER RESET
231

FIG. 6

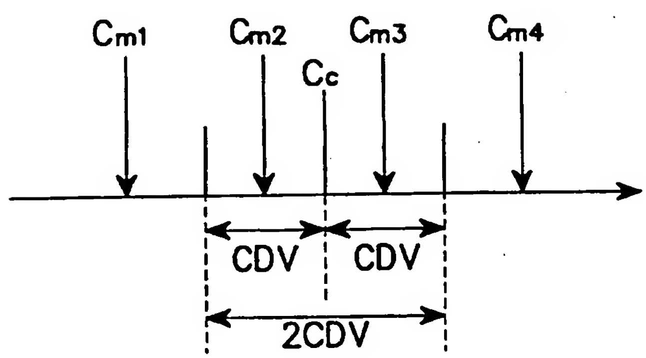


FIG. 7

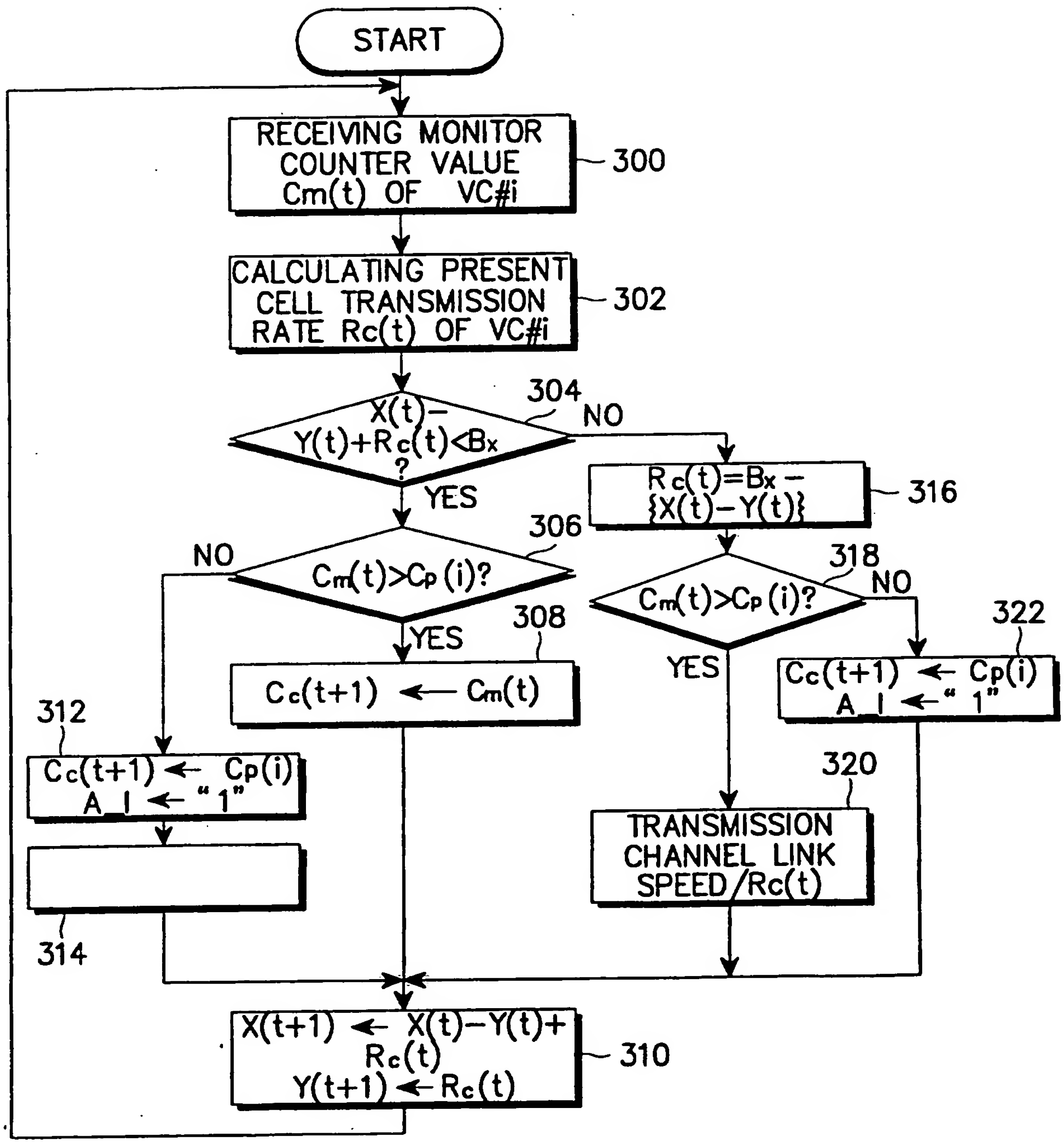

START
RECEIVING MONITOR COUNTER VALUE Cm(t) OF VC#i
300
CALCULATING PRESENT CELL TRANSMISSION RATE Rc(t) OF VC#i
302
X(t)−Y(t)+Rc(t)<Bx ?
304
NO
YES
Rc(t)=Bx − {X(t)−Y(t)}
316
Cm(t)>Cp(i)?
306
NO
YES
308
Cc(t+1) ← Cm(t)
318
Cm(t)>Cp(i)?
NO
YES
322
Cc(t+1) ← Cp(i)
A_I ← "1"
312
Cc(t+1) ← Cp(i)
A_I ← "1"
320
TRANSMISSION CHANNEL LINK SPEED/Rc(t)
314
X(t+1) ← X(t)−Y(t)+Rc(t)
Y(t+1) ← Rc(t)
310

FIG. 8

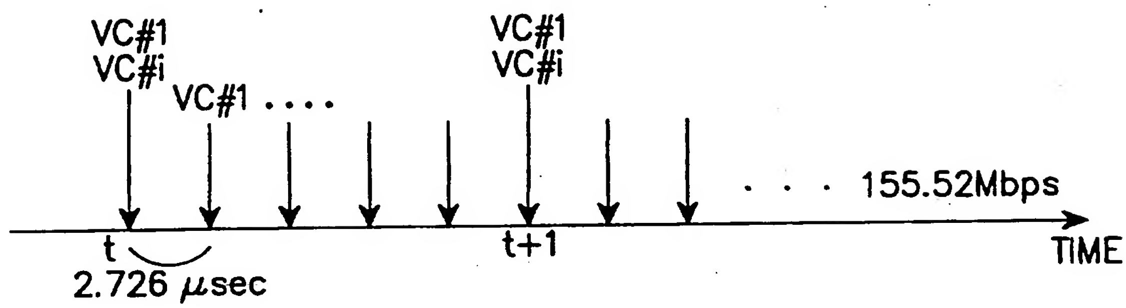


FIG. 9

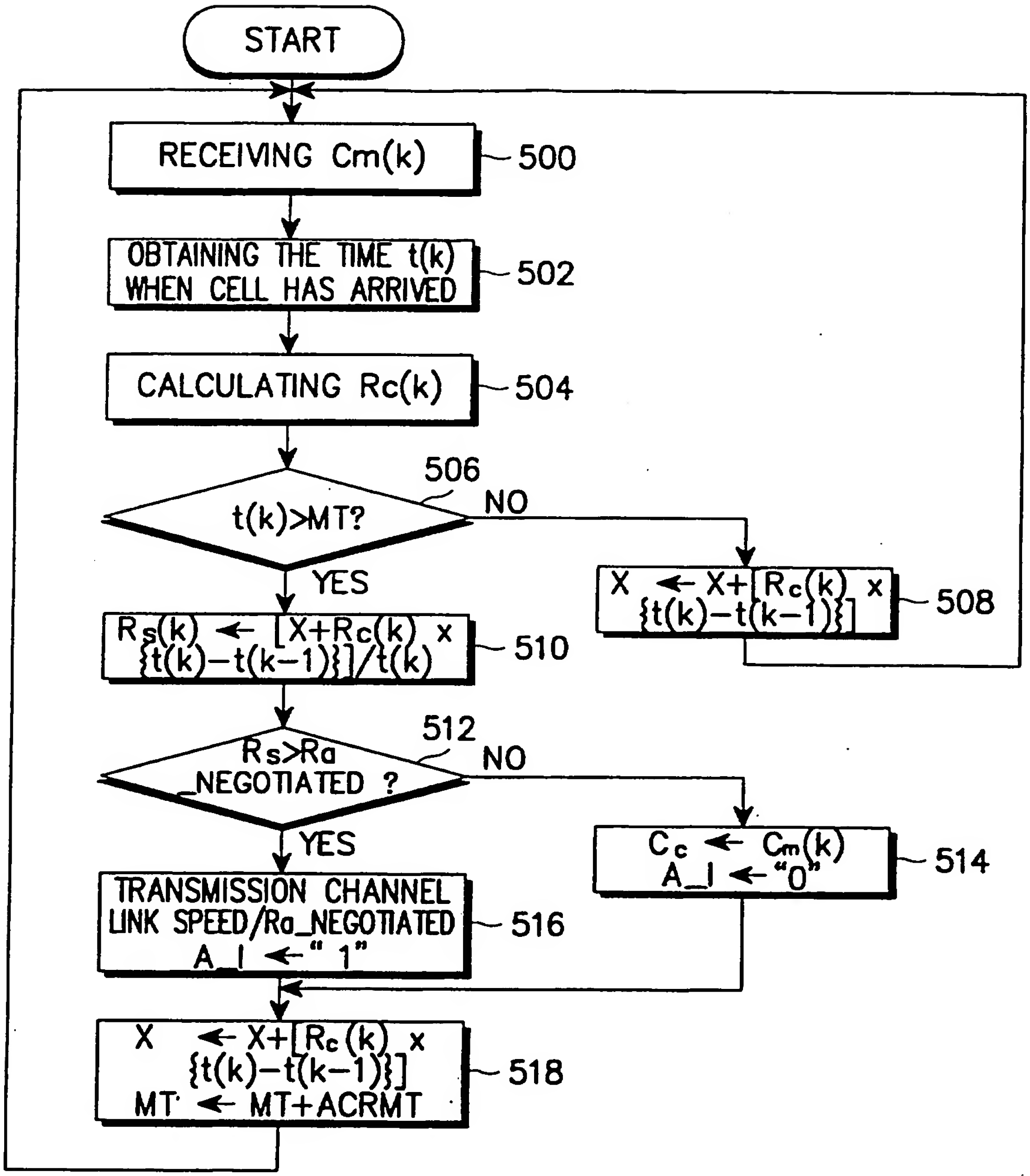

START
RECEIVING Cm(k)
500
OBTAINING THE TIME t(k) WHEN CELL HAS ARRIVED
502
CALCULATING Rc(k)
504
506
t(k)>MT?
NO
YES
X ← X+[Rc(k) x {t(k)−t(k−1)}]
508
Rs(k) ← [X+Rc(k) x {t(k)−t(k−1)}]/t(k)
510
512
Rs>Ra_NEGOTIATED ?
NO
YES
Cc ← Cm(k)
A_I ← "0"
514
TRANSMISSION CHANNEL LINK SPEED/Ra_NEGOTIATED
A_I ← " 1"
516
X ← X+[Rc(k) x {t(k)−t(k−1)}]
MT ← MT+ACRMT
518

FIG. 10